TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Nutrients

Lower St. Johns River

Prepared by:

US EPA Region 4
61 Forsyth Street SW
Atlanta, Georgia 30303

January 2008

United States Environmental Protection Agency

Region 4 serving the southeast

Table of Contents

List of Figures

List of Tables

In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C §1251 et. seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S. Environmental Protection Agency is hereby establishing Total Maximum Daily Load (TMDL) for Nutrients in the Lower St. Johns River Basin (WBIDs 2213A through 2213N). Subsequent actions must be consistent with this TMDL.

/s/ 01/17/08

James D. Giattina Date
Director
Water Management Division

Acknowledgments

The U.S. Environmental Protection Agency (EPA) would like to acknowledge that the contents of this report and the Total Maximum Daily Load (TMDL) contained herein were developed by the Florida Department of Environmental Protection (FDEP).

The development of this TMDL was a cooperative effort between FDEP, the St. Johns River Water Management District (SJRWMD) and the EPA. Throughout the several years that this project spanned, there was excellent cooperation and coordination between the staff of the two agencies and EPA wishes to express its appreciation to FDEP and SJRWMD for its cooperative spirit.

While this was a joint effort between the EPA and FDEP, the authors want to acknowledge that the main work that constitutes the scientific basis for the TMDL (the determination of the river's assimilative capacity) was conducted by SJRWMD staff. In particular, John Hendrickson and Pete Sucsy should be commended for their outstanding contributions and unwavering dedication to completing the modeling work. Thanks to their efforts, the water quality model for the Lower St. Johns River (LSJR) is undoubtedly one of the best in the nation, and will likely result in improved modeling for other TMDLs as other practitioners adopt some of the innovations/adaptations that John and Pete incorporated into the LSJR model.

We also wish to thank and acknowledge the contributions of staff from FDEP's Northeast District office. Special thanks are due to Jim Maher and Jeremy Richarde for their continuous contributions as technical reviewers and liaison with local stakeholders who participated in the meetings of the LSJR Technical Advisory Committee, the TMDL Stakeholders Committee, and the TMDL Executive Committee. Their work to develop the starting points for the point source loads and the allocation spreadsheets was particularly invaluable, and we simply could not have completed the project without their outstanding contributions. We also thank former Northeast District Manager Ernie Frey and current District Manager Mario Taylor for their dedication to the TMDL Program and their leadership of the LSJR Executive Committee. We are particularly thankful for the gusto with which Mario embraced his leadership role in the TMDL development process.

Additional thanks are due to Tiffany Busby for her work in facilitating coordination between the agencies and with the LSJR Technical Advisory Committee, the TMDL Stakeholders Committee, and the TMDL Executive Committee. And finally, we wish to express our appreciation for all of the many people who gave their time to participate in the Technical Advisory Committee meetings, Stakeholder Committee meetings, and Executive Committee meetings. We are confident that the resultant TMDL was improved by all of those who participated in this process.

LIST OF ABBREVIATIONS

AWT	Advanced Waste Treatment
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biological Oxygen Demand
CBODu	Ultimate Carbonaceous Biological Oxygen Demand
CFS	Cubic Feet per Second
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
F.A.C.	Florida Administrative Code
GIS	Geographic Information System
HUC	Hydrologic Unit Code
JEA	Jacksonville Electrical Authority
LA	Load Allocation
MGD	Million Gallons per Day
MHP	Mobile Home Park
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
Rf3	Reach File 3
RM	River Mile
RMSE	Root Mean Square Error
SOD	Sediment Oxygen Demand
SSAC	Site Specific Alternative Criteria
TBN	Total Bioavailable Nitrogen
TBP	Total Bioavailable Phosphorus
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
WBID	Water Body Identification
WLA	Waste Load Allocation
WWTP	Wastewater Treatment Plan

SUMMARY SHEET
Total Maximum Daily Load (TMDL)

- 303(d) Listed Waterbody Information
  State: Florida
  HUC: 03080103

1998 303(d) Listing of Impaired Waterbody

WBID	Segment Name	Classification	Constituent
2213A	St. Johns River above Mouth	Marine	Nutrients
2213B	St. Johns River above ICWW	Marine	Nutrients
2213C	St. Johns River above Dames Pt.	Marine	Nutrients
2213D	St. Johns River above Trout River	Marine	Nutrients
2213E	St. Johns River above Warren Bridge	Marine	Nutrients
2213F	St. Johns River above Piney Pt	Marine	Nutrients
2213G	St. Johns River above Doctors Lake	Marine	Nutrients
2213H	St. Johns River above Julington Creek	Marine	Nutrients
2213I	St. Johns River above Black Creek	Fresh	Nutrients
2213J	St. Johns River above Palmo Creek	Fresh	Nutrients
2213K	St. Johns River above Tocio	Fresh	Nutrients
2213L	St. Johns River above Federal Point	Fresh	Nutrients
2213M	St. Johns River above Rice Creek	Fresh	Nutrients
2213N	St. Johns River above Dunns Creek	Fresh	Nutrients

- TMDL Endpoint (i.e., Target):

  The State of Florida has narrative water quality criteria for nutrients.

  > 62-302.530(48)(a) The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man induced nutrient enrichment (total nitrogen and total phosphorus) shall be

considered degradation in relation to the provisions of Section 62-302.300, 62-302.700, and 62-4.242, FAC.

62-302.530(48)(b) In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.

The State of Florida has water quality criteria for dissolved oxygen.

62-302.530(31) Shall not average less that 5.0 in a 24 hour period and shall never be less than 4.0. Normal daily and seasonal fluctuations above these levels shall be maintained.

- TMDL Approach

The Pollutant Load Screening Model (PLSM) was used to estimate seasonal nutrient loads in the watershed. A three dimensional hydrodynamic model (EFDC) was used to predict the complex transport patterns in the Lower St. Johns River as a function of wind, tide and salinity intrusion. The results of the hydrodynamic model were incorporated in a three dimensional water quality model which predicts the impacts of nutrient loadings (both point and nonpoint sources) on chlorophyll-a, dissolved oxygen as well as other water quality parameters.

- TMDL Allocation:

WBIDs	Parameter	TMDL (kg/year)	WLA (kg/year)	LA (kg/year)	MOS
2213I to 2213M	Total Nitrogen (TN)	8,571,563	236,695	8,394,868	Implicit
2213I to 2213M	Total Phosphorus (TP)	471,025	44,331	426,694	Implicit

WBIDs	Parameter	TMDL (kg/year)	WLA (kg/year)	LA (kg/year)	MOS
2213A to 2213H	Total Nitrogen	1,376,855	1,027,590	349,265	Implicit

- Endangered Species (yes or blank): Yes

- EPA Lead on TMDL (EPA or blank): EPA

- TMDL Considers Point Source, Nonpoint Source, or both: Both

Major NPDES Discharges to surface waters in the watershed:

Name of Facility	Facility ID	Permitted Flow (mgd)	1997-98 Nutrients TN (mg/L)	1997-98 Nutrients TP (mg/L)
SMURFIT-STONE CONTAINER CORPORATION	FL0000400	20	6.8	1.1
JEFFERSON SMURFIT – JAX	FL0000892	6	8.8	1.2
USN – NS MAYPORT WWTF	FL0000922	2	3.2	2.1
USN – NAS JACKSONVILLE WWTF	FL0000957	3	8.5	1.7
GEORGIA-PACIFIC	FL0002763	40	5.5	1.4
JACKSONVILLE BEACH WWTF	FL0020231	4.5	9.1	2.2
NEPTUNE BEACH WWTF	FL0020427	1.5	8.8	1.4
GREEN COVE SPRINGS – Harbor Road WWTF	FL0020915	0.75	9.2	2.9
WESMINSTER WOODS – (Wesley Manor Retirement Village)	FL0022489	0.09	4.6	2.0
ATLANTIC BEACH – BUCCANEER WWTF	FL0023248	1.9	13.4	1.4
JEA – MANDARIN WWTF	FL0023493	7.5	5.34	2.3
JEA – MONTEREY WWTF (operated by UWF)	FL0023604	3.6	11.3	2.6
JEA – HOLLY OAKS WWTF (formerly UWF)	FL0023621	1	8.3	2.1
JEA – SAN JOSE WWTF (formerly UWF)	FL0023663	2.25	10.0	2.9
JEA – JACKSONVILLE HEIGHTS WWTF (formerly UWF)	FL0023671	2.5	10.1	2.9
ORANGE PARK WWTF	FL0023922	2.5	-	3.7
JEA – SAN PABLO WWTF (formerly UWF)	FL0024767	0.75	6.5	3.5
CCUA – MILLER STREET WWTF	FL0025151	4.99	4.5	3.2
JEA – ORTEGA HILLS WWTF (formerly UWF)	FL0025828	0.22	16.8	2.3
JEA – BUCKMAN WWTF	FL0026000	52.5	10.5	4.7
JEA – ARLINGTON WWTF	FL0026441	20	14.3	2.6
JEA – NORTHEAST WWTF (aka JEA – DISTRICT II WWTF)	FL0026450	10	22.7	5.9
JEA – SOUTHWEST WWTF	FL0026468	10	10.5	1.4

Name of Facility	Facility ID	Permitted Flow (mgd)	1997-98 Nutrients	
			TN (mg/L)	TP (mg/L)
JEA – ROYAL LAKES WWTF (formerly UWF)	FL0026751	3.25	7.8	3.8
FWSC – BEACON HILLS SD WWTF	FL0026778	1.3	11.9	2.0
FWSC – WOODMERE SD WWTF	FL0026786	0.7	11.6	1.7
GREEN COVE SPRINGS – SOUTH WWTF	FL0030210	0.5	13.6	2.3
CCUA – FLEMING OAKS WWTF	FL0032875	0.49	3.0	1.9
ATLANTIC BEACH – MAIN WWTF (D001)	FL0038776	3	11.4	2.1
PALATKA WWTF	FL0040061	3	14.7	2.4
ANHEUSER BUSCH – MAIN ST – LAND APP	FL0041530	2.6	3.9	0.3
HASTINGS WWTF	FL0042315	0.12	4.5	0.6
JEA – JULINGTEEN CREEK WWTP	FL0043591	0.476	12.0	3.0
CCUA - FLEMING ISLAND WWTF (combined)	FL0043834	6.365	-	-
UWF – SAINT JOHNS NORTH WWTF	FL0117668	-	6.5	1.7
BRIERWOOD SD – BEAUCLERC STP	FL0023370	-	-	-

1 Introduction

1.1 Purpose of Report

This document presents Total Maximum Daily Loads (TMDLs) for total nitrogen (TN) and total phosphorus (TP) for the Lower St. Johns River (LSJR). The river was determined to be impaired by nutrients based on elevated chlorophyll *a* and Trophic State Index (TSI) levels in the freshwater and marine portions of the river, and was included on Florida's 1998 list of impaired waters. Florida has also identified the Lower St. Johns River Basin (LSJRB) on a subsequent update to that 1998 list through a Secretarial Order adopted on September 4, 2003. The TMDLs establish the allowable loadings of TN and TP to the freshwater and marine portions of the LSJR that would restore the river so that it meets its applicable water quality criteria for nutrients and dissolved oxygen (DO).

1.2 Development of the TMDL

This TMDL was developed in cooperation with the St. Johns River Water Management District (SJRWMD) as part of its development of Pollutant Load Reduction Goals (PLRGs) for the river. In recognition of the eutrophication-related impairment of the river, the Florida Department of Environmental Protection (FDEP) and the St. Johns River Water Management District (SJRWMD) cooperatively developed a draft Plan of Study (POS) for the TMDL (Hendrickson and Magley, 2001) before the river was assessed for impairment under Rule 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR). As indicated in the POS, the SJRWMD (in conjunction with its contractor, the U.S. Army Corps of Engineers) was the lead agency for modeling activities, including the development of a watershed model to estimate nonpoint source loads and the development of a linked hydrologic/water quality model to determine the assimilative capacity of the river.

FDEP and SJRWMD also actively coordinated with a variety of local stakeholders throughout the TMDL development process, including meetings to discuss the POS and subsequent monthly meetings (for over a year) with a TMDL Stakeholders Committee and a TMDL Executive Committee. The TMDL Executive Committee is a broad-based stakeholder group that was convened by FDEP's Northeast District in July 2002 (see Appendix A for membership). It has advised FDEP on such issues as water quality targets and allocation processes. While FDEP is clearly charged with implementing the TMDL Program, including the adoption of this TMDL by rule, this TMDL reflects the recommendations of the TMDL Executive Committee.

1.3 Revision of the TMDL

A nutrient TMDL for the LSJR was originally adopted by Florida on December 3, 2003 [Rule 62-304.415, Florida Administrative Code (FAC)] and formally submitted to EPA Region 4 on March 15, 2004. EPA approved the TMDL on April 27, 2004. EPA's approval was challenged on the basis that the Class III marine daily average DO criterion would not be met at all times under the TMDL. EPA ultimately rescinded its April 27, 2004 approval, and subsequently established a nutrient TMDL for the Lower St. Johns River in January 2006.

This TMDL document represents a reassessment of EPA's January 2006 TMDL, based on a site-specific alternative criterion (SSAC) for dissolved oxygen for the marine portion of the Lower St. Johns River that was adopted by the State and approved by EPA.

1.4 Identification of Waterbody

The LSJR is that portion of the St. Johns River that flows between the mouth of the Ocklawaha River, its largest tributary, and the Atlantic Ocean, encompassing a 2,750-square-mile (mi^2) drainage area (Figure 1). Within this reach, the St. Johns River is 101 miles long and has a water surface area of approximately 115 square miles. Major centers of population within the LSJRB include Palatka, a city of 10,700 at the southern entrance to the basin; Green Cove Springs, a city of 4,700 at the midpoint; and the Orange Park, Middleburg, and Jacksonville metropolitan area, with a population of over 1 million, in the northern portion of the basin (Floyd *et al.,* 1997). The LSJR is a sixth-order, darkwater river estuary, and, along its length, it exhibits characteristics associated with riverine, lake, and estuarine aquatic environments (Phlips *et al.,* 2000). Additional information about the river's hydrology and geology are available in the Basin Status Report for the LSJRB (FDEP, 2002).

The LSJR is divided into three ecological zones based on salinity (Figure 2). The three zones are as follows: 1) a predominantly freshwater, tidal lakelike zone that extends from the city of Palatka north to the mouth of Black Creek; 2) an alternately freshwater and marine, oligohaline zone extending from Black Creek northward to the Fuller Warren Bridge (I-95) in Jacksonville; and 3) a predominantly marine and much narrower zone downstream from I-95 to the mouth (Hendrickson and Konwinski, 1998).

For assessment purposes, FDEP has divided the LSJRB into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. The main stem of the LSJR is divided into fifteen segments, as shown in Figure 3.

Figure 1 The Lower St. Johns River

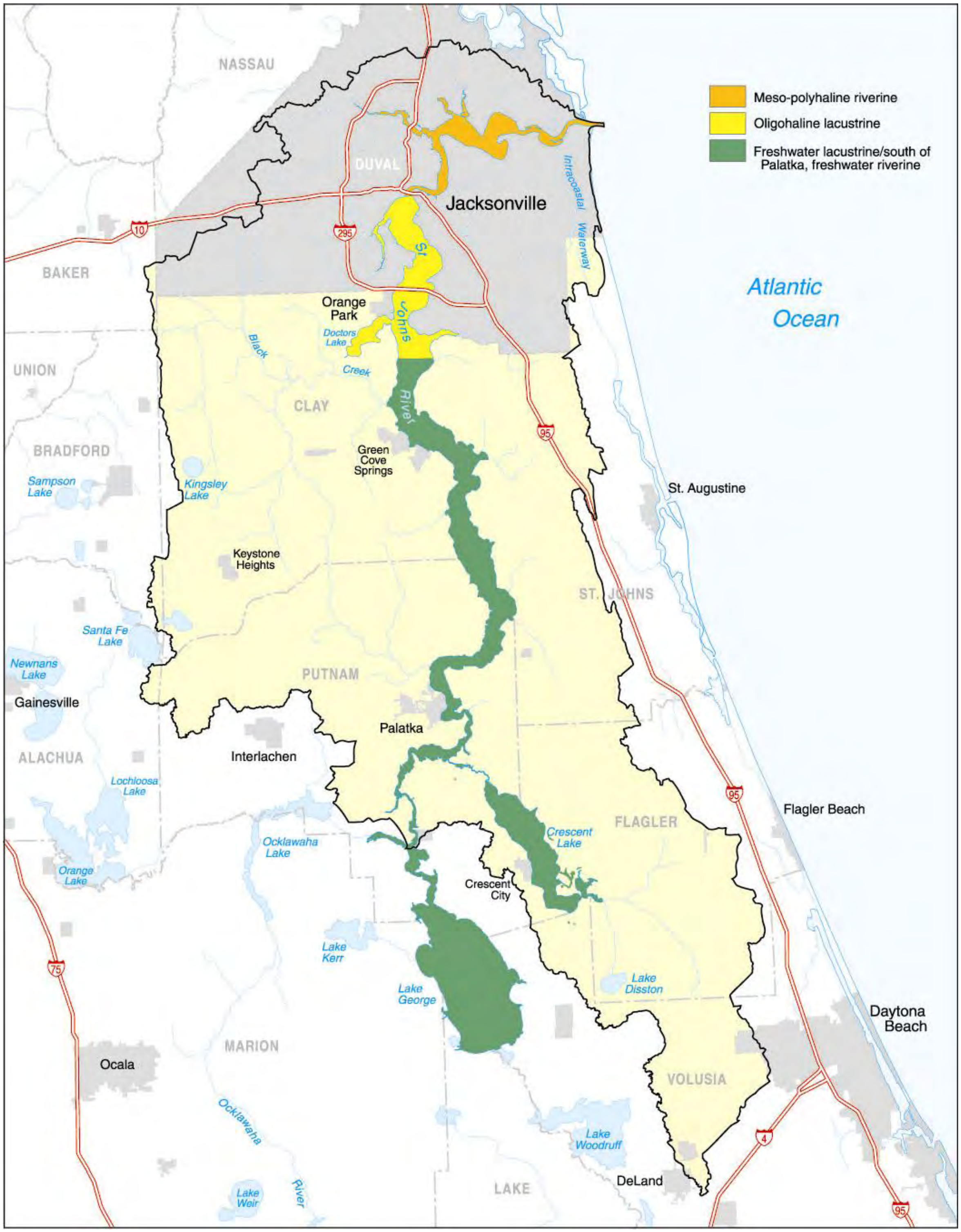

Figure 2 Ecological Zones of the Lower St. Johns River Basin

(Note: This figure inadvertently includes Lake George, which is not part of the LSJRB.)

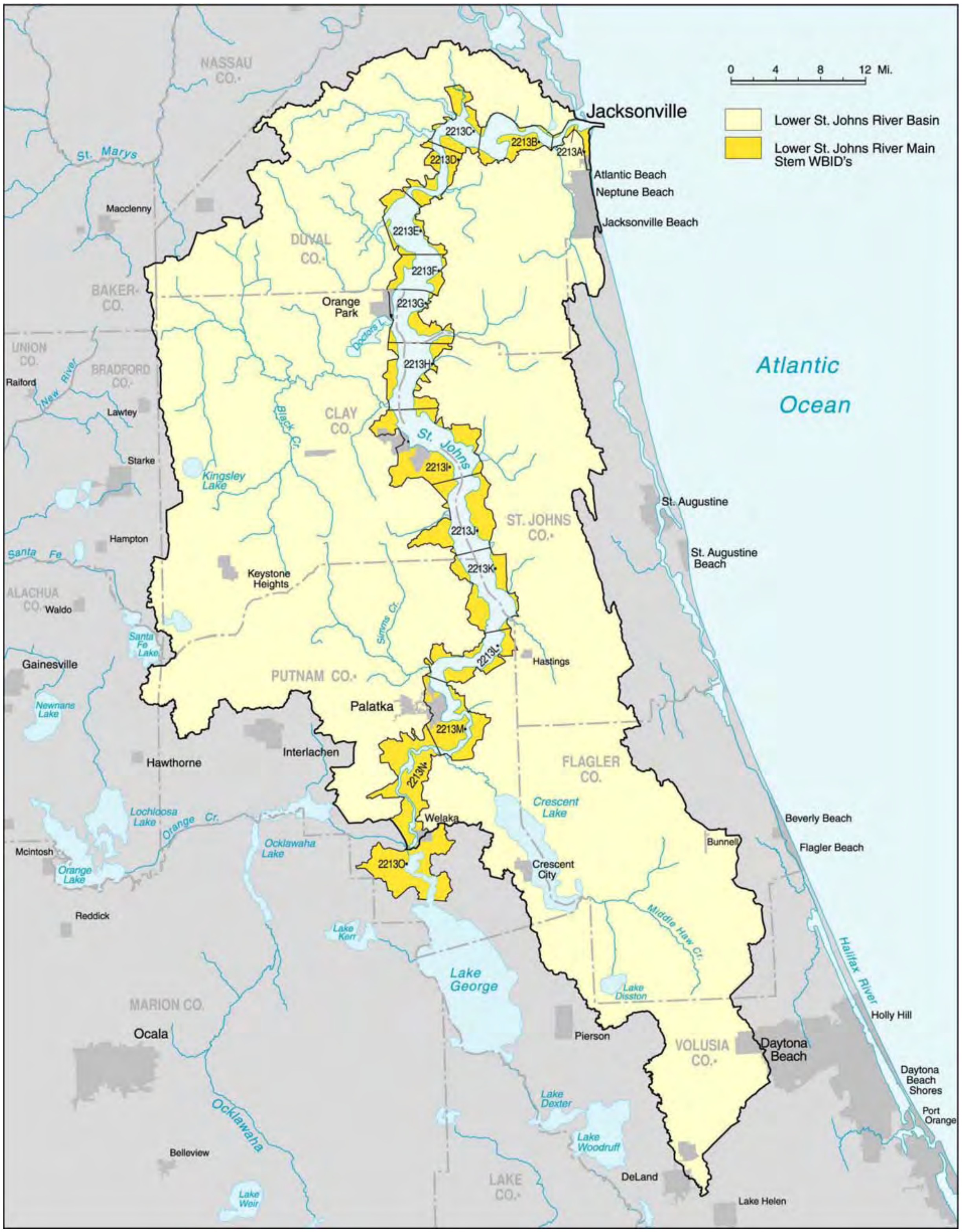

Figure 3 Waterbody Identification Numbers for the Main Stem of the LSJR

2 Statement of Water Quality Problem

2.1 Verified Nutrient Impairment of the LSJR

Section 303(d) of the Federal Clean Water Act requires states to submit to the Environmental Protection Agency (EPA) lists of waters that are not fully meeting their applicable water quality standards. FDEP has developed such lists, commonly referred to as 303(d) lists, since 1992, and identified the LSJR as impaired by excess nutrients on the 1998 list.

FDEP has subsequently reassessed the main stem of the LSJR and, again, determined that the majority of the freshwater and estuarine segments of the river are impaired by nutrients (see Table 1). As noted in Table 1, eleven of the fifteen LSJR segments were determined to be impaired by nutrients based on annual mean chlorophyll *a* concentrations or annual mean Trophic State Index (TSI) values. Annual mean chlorophyll *a* and TSI values for the assessment period for each segment are provided in Appendix I. FDEP's assessment was adopted by Secretarial Order on September 4, 2003. Impairment associated with parameters other than nutrients will be addressed in separate TMDL development efforts in the time frames indicated in the table.

Table 1 Verified Impaired Segments of the Main Stem of the LSJR

WBID	Waterbody Segment	Parameters of Concern	Priority for TMDL Development	Projected Year for TMDL Development
2213A	STJ RIV AB MOUTH	NUTRIENTS (HISTCHLA)	LOW	2008
2213A	STJ RIV AB MOUTH	IRON	MEDIUM	2008
2213B	STJ RIV AB ICWW	NUTRIENTS (HISTCHLA)	MEDIUM	2008
2213B	STJ RIV AB ICWW	LEAD	MEDIUM	2008
2213B	STJ RIV AB ICWW	COPPER	MEDIUM	2008
2213B	STJ RIV AB ICWW	IRON	MEDIUM	2008
2213B	STJ RIV AB ICWW	NICKEL	MEDIUM	2008
2213C	STJ RIV AB DAMES PT	NUTRIENTS (HISTCHLA)	(HIGH)	(2002)
2213C	STJ RIV AB DAMES PT	COPPER	MEDIUM	2008
2213C	STJ RIV AB DAMES PT	IRON	MEDIUM	2008
2213C	STJ RIV AB DAMES PT	NICKEL	MEDIUM	2008
2213D	STJ RIV AB TROUT RIV	COPPER	MEDIUM	2008
2213D	STJ RIV AB TROUT RIV	IRON	MEDIUM	2008
2213D	STJ RIV AB TROUT RIV	NICKEL	MEDIUM	2008
2213E	STJ RIV AB WARREN BRG	NUTRIENTS (CHLA)	(HIGH)	(2002)
2213E	STJ RIV AB WARREN BRG	COPPER	MEDIUM	2008
2213E	STJ RIV AB WARREN BRG	IRON	MEDIUM	2008
2213F	STJ RIV AB PINEY PT	NUTRIENTS (CHLA)	(HIGH)	(2002)
2213I	STJ RIV AB BLACK CK	NUTRIENTS (TSI)	MEDIUM	2008
2213J	STJ RIV AB PALMO CK	NUTRIENTS (TSI)	MEDIUM	2008
2213K	STJ RIV AB TOCIO	NUTRIENTS (TSI)	HIGH	2002
2213L	STJ RIV AB FEDERAL PT	NUTRIENTS (TSI)	HIGH	2002
2213M	STJ RIV AB RICE CK	NUTRIENTS (CHLA)	MEDIUM	2008
2213N	STJ RIV AB DUNNS CK	NUTRIENTS (CHLA)	MEDIUM	2008
2213G	STJ RIV AB DOCTOR LAKE	CADMIUM	MEDIUM	2008
2213I	STJ RIV AB BLACK CK	SILVER	MEDIUM	2008

Note: Table 1 also includes segments impaired by parameters other than nutrients (certain metals). These parameters are shown to provide a complete picture of the impairment in the river, but this TMDL only addresses the nutrient impairment.

2.2 Other Indications of Nutrient Impairment

In addition to the elevated chlorophyll *a* values (algal blooms) and low DO levels, a number of widespread water quality problems have been identified throughout the river that are indicative of an imbalance in the flora and fauna of the LSJR (FDEP, 2002). These problems include the following: a) fish kills; b) submersed aquatic shoreline vegetation covered in algal mats; c) excessive epiphyte growth further blocking light from submerged aquatic vegetation, d) anecdotal accounts of shoreline vegetation losses and reduced recreational fishing quality; e) river sediment conditions indicative of low benthic animal diversity; f) excessive organic matter sedimentation and prolonged anoxia; and g) the presence of potentially toxic dinoflagellates such as the *Pfiesteria*-like *Crytoperidiniopsoids* (Burkholder and Glasgow, 1997a, 1997b) and *Prorocentrum minimum* (Phlips et al., 2000), often co-occurring with fish kills or ulcerative disease syndrome in fish. All of these problems are connected by a common thread – they indicate accelerated eutrophication in an estuarine environment (see Appendix B for a discussion of eutrophication).

Numerous other studies have identified either high nutrient concentrations or eutrophic conditions (Bricker *et al.*, 1999; EPA, 2001; Janicki, 2000) in the LSJR. In their assessment of nutrient loads to the LSJR and their potential effects, Hendrickson and Konwinski (1998) determined the following:

1) A combination of point and nonpoint source pollution has increased the within-basin nutrient load to the LSJR 2.4 times over natural background for TN and 6 times for TP;

2) Areal nutrient loading, at 9.7 and 2.1 kilograms of nitrogen and phosphorus per hectare of watershed contributing area per year in the LSJRB, is one of the highest reported from studies in the southeastern United States;

3) Point sources were the greatest contributor of anthropogenic nutrient load from within the basin. However, due to the entry of this load nearer to the mouth of the river, its incremental effect is presumed to be less than that caused by nonpoint sources and upper and middle St. Johns River loads that enter upstream; and

4) Changes in the amounts of river algae appear to correlate significantly with changes in inorganic nitrogen and DO, suggesting that algae use much of the nitrogen supplied to them for growth. During this cycle of growth and ultimate death, the algae exert a dominant influence over river oxygen content.

Based on these findings, it is clear that the LSJR receives high nutrient loads and is nutrient enriched, and that it exhibits the symptoms of estuarine eutrophication. While nutrient enrichment is not the only problem leading to impaired water quality in the LSJR, it is probably the most widespread and multifaceted.

3 Description of Applicable Water Quality Standards and Water Quality Targets

3.1 Classification of the LSJR and Criteria Applicable to TMDL

The LSJR is a Class III waterbody, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the impairment addressed by this TMDL are the dissolved oxygen (DO) criterion and the narrative nutrient criterion. It should be noted that none of the LSJR WBIDs were verified for DO impairment using the IWR methodology, which uses a 10 percent exceedance frequency to verify impairment. However, continuous DO monitoring data collected in both the freshwater and marine reaches of the river (at the Dames Point Bridge station and, to a lesser extent, the Acosta Bridge station) from 1996 through 2001 indicated periods when DO concentrations were below the criterion in each of these portions of the river. As these values were at levels that could adversely impact aquatic fauna, the nutrient TMDL also needs to address the impact of nutrients on DO levels.

3.2 Dissolved Oxygen Criterion

Florida's water quality standards for Class III waters include statewide criteria for DO which vary depending on whether a waterbody is "predominantly marine"[1] or "predominantly fresh." The Class III DO criterion for predominantly fresh waters is a minimum DO of 5 milligrams per liter (mg/L), and the criterion for predominantly marine zones is a minimum DO of 4 mg/L, with a minimum daily average of 5 mg/L. See Rule 62-302.xxx, F.A.C. Florida's water quality standards also provide that a site specific alternative criterion (SSAC) may be established where that alternative criterion is demonstrated, based on scientifically defensible methods, to protect existing and designated uses for a particular waterbody. See Rule 62-302.800(2) FDEP, in cooperation with the SJRWMD, established site specific alternative criteria for DO for the estuarine portions of the LSJR. FDEP submitted the SSAC to EPA for review on June 20, 2006. EPA approved the SSAC on October 10, 2006, making the SSAC the applicable water quality standard for DO for the River.

FDEP developed the LSJR SSAC using a methodology developed by EPA and documented in *Ambient Water Quality Criteria for Dissolved Oxygen (Salt Water): Cape Cod to Cape Hatteras* (EPA, 1999). This methodology provides for a more appropriate DO criterion because it addresses both absolute minimum DO values for the protection against acute effects and sublethal DO values for the protection against reductions in growth and recruitment. Under the EPA methodology, these values are combined into one relationship, termed the "persistent exposure criteria," that can be used to evaluate the intensity and duration of a given low DO event. FDEP's application of the EPA methodology to develop a SSAC for DO for the marine

[1] Surface waters in which the surface chloride concentration at the surface is greater than or equal to 1,500 milligrams per liter (mg/L) are considered "predominantly marine" (Rule 62-302, F.A.C.).

portion of the river between Julington Creek and the mouth was documented in the document, *Site Specific Alternative Dissolved Oxygen Criterion to Protect Aquatic Life in the Marine Portions of the Lower St. Johns River Technical Support Document, which is provided as* Appendix L. The SSAC was expressed as follows:

> The first part of the SSAC is a minimum DO concentration of 4.0 mg/L. In addition, the Total Fractional Exposure to DO levels in the 4.0 to 5.0 mg/L range must also be at or below 1.0 for each annual evaluation period as determined by the equation:

$$\left(\begin{array}{c}\textbf{Total Fractional}\\ \textbf{Exposure}\end{array}\right)=\frac{\begin{array}{c}\textbf{Days between}\\ \textbf{4.0 - < 4.2 mg/L}\end{array}}{\textbf{16 day Max}}+\frac{\begin{array}{c}\textbf{Days between}\\ \textbf{4.2 - < 4.4 mg/L}\end{array}}{\textbf{21 day Max}}+\frac{\begin{array}{c}\textbf{Days between}\\ \textbf{4.4 - < 4.6 mg/L}\end{array}}{\textbf{30 day Max}}+\frac{\begin{array}{c}\textbf{Days between}\\ \textbf{4.6 - < 4.8 mg/L}\end{array}}{\textbf{47 day Max}}+\frac{\begin{array}{c}\textbf{Days between}\\ \textbf{4.8 - < 5.0 mg/L}\end{array}}{\textbf{55 day Max}}$$

> where the number of days within each interval is based on the daily average DO concentration.

3.3 Nutrient Criterion

Florida's nutrient criterion is narrative only — nutrient concentrations in a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. As part of the PLRG development, the SJRWMD established a site-specific threshold for nutrient impairment for the freshwater zone based on chlorophyll *a* values (Hendrickson *et al.*, 2003). Hendrickson evaluated the maximum algal biomass levels that would: 1) maintain the diversity of the plankton community; 2) facilitate the upward transfer of primary production to higher trophic levels (and maintain zooplankton diversity); and 3) minimize the potential dominance of detrimental algal species and the production of algal toxins. He found that a chlorophyll *a* target of 40 micrograms per liter (µg/L), not to be exceeded more than 10 percent of the time, would protect the aquatic flora and fauna of the river. Studies have shown that when chlorophyll *a* levels rise above 40 µg/L, a shift in algal types occurs: blue-green algae begin to dominate the system, toxic algal species begin to increase, and zooplankton communities begin to decline.

This alternative threshold for the freshwater portion of the river was discussed extensively at several meetings of the LSJR TMDL Stakeholders Committee and TMDL Executive Committee, and both groups recommended it be used for this TMDL rather than the IWR threshold. These groups also recommended that the threshold be applied over a long-term period (several years representing slightly drier than average conditions), rather than a worst-case, dry year. FDEP agreed with these recommendations and established the TMDL using the alternative chlorophyll *a* threshold and long-term average model output, rather than model predictions for a worst case year.

Maintaining chlorophyll *a* levels below 40 µg/L 90 percent of the time should prevent an imbalance in natural populations of aquatic flora and fauna under average conditions, and combined with other conservative aspects of the modeling (e.g., focusing on the worst-case WBID) should protect the river during low-flow conditions as well. However, there is some uncertainty whether these levels will be fully protective in this portion of the river under critical, low-flow conditions or during the extended growing season with less than average flows. For this reason, the river system will continue to be evaluated to determine if a seasonal average maximum or yearly average maximum level of chlorophyll *a* should be established to protect against imbalances in natural populations of aquatic flora and fauna.

Specifically, studies will be conducted to demonstrate the following: 1) that progress is being made towards reducing nutrient loads by the required 30 percent or that progress towards reaching the percent reduction goal is being made; 2) that once the 30 percent reduction goal is reached, it results in chlorophyll *a* levels that do not exceed 40 µg/L more than 10 percent of the time; and 3) that once the chlorophyll *a* target is reached, it has resulted in the achievement of the narrative nutrient criterion (i.e., balanced, natural populations of aquatic flora and fauna).

4 DETERMINATION OF CURRENT LOADING

4.1 Types of Sources

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of nutrients in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term point sources has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, runoff from agriculture, runoff from silviculture, runoff from mining, discharges from failing septic systems, and atmospheric deposition.

The 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination Program (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see Appendix E for background information on the state and federal stormwater programs). Therefore, the term "point source" describes traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see Section 6). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Background

This section describes the approach used to determine external nutrient loads to the LSJR. The external load assessment was intended to determine the spatial and temporal characteristics of the external load to the LSJR and, ultimately, the effectiveness and costs associated with strategies for reducing this load. Assessing the external load entailed monitoring and research projects to determine the volume, concentration, timing, location, and underlying nature of point, nonpoint, and atmospheric source additions to the river stem and tributary mouths below the head of tide. The subsections below describe the approaches used for assessing each of these major external load categories. Figure 4 identifies tributary water quality sampling stations, stream gauging stations, and major point sources in the basin. Because the computations involved in the development of the external load for the LSJR are so instrumental in the outcome of TMDLs and PLRGs, they are reported in a separate document (Hendrickson *et al.,* 2003).

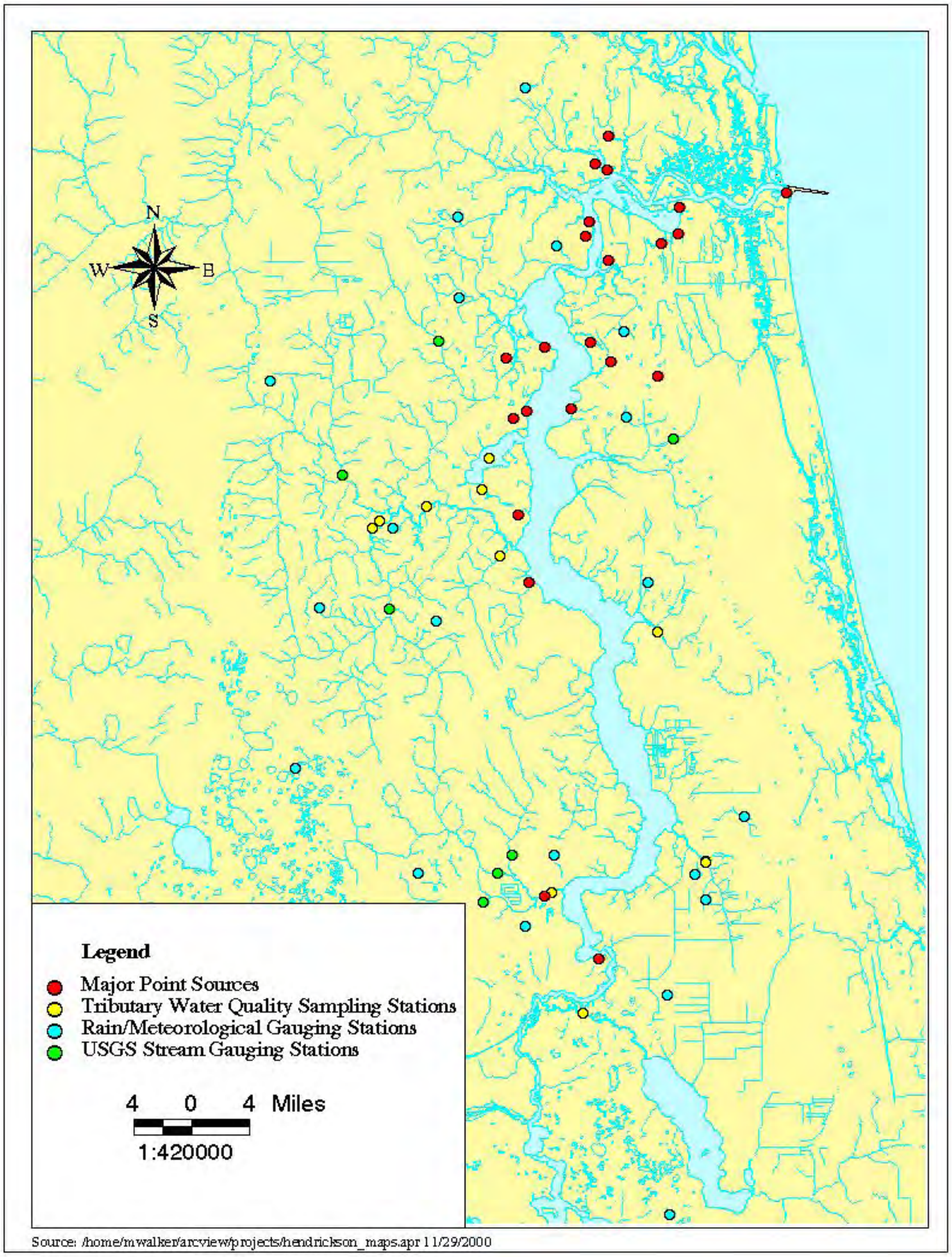

Figure 4 Data Collection and Monitoring Stations of the External Load Assessment

4.3 Permitted Point Sources

4.3.1 Inventory of Point Sources

There are 36 permitted wastewater treatment facilities that discharge nutrient loads directly into the LSJR (Table 2), comprised of 32 domestic wastewater facilities and 4 industrial wastewater facilities. These facilities, which are permitted through the NPDES Program, are estimated to contribute approximately 27 percent and 55 percent of the annual average above-background TN and TP loads, respectively, to the LSJR.

Table 2 Permitted Wastewater Facilities Discharging to the LSJR

Name of Facility	Facility ID	Permitted Flow (mgd)	1997-98 Nutrients	
			TN (mg/L)	TP (mg/L)
SMURFIT-STONE CONTAINER CORPORATION	FL0000400	20	6.8	1.1
JEFFERSON SMURFIT – JAX	FL0000892	6	8.8	1.2
USN – NS MAYPORT WWTF	FL0000922	2	3.2	2.1
USN – NAS JACKSONVILLE WWTF	FL0000957	3	8.5	1.7
GEORGIA-PACIFIC	FL0002763	40	5.5	1.4
JACKSONVILLE BEACH WWTF	FL0020231	4.5	9.1	2.2
NEPTUNE BEACH WWTF	FL0020427	1.5	8.8	1.4
GREEN COVE SPRINGS – Harbor Road WWTF	FL0020915	0.75	9.2	2.9
WESMINSTER WOODS – (Wesley Manor Retirement Village)	FL0022489	0.09	4.6	2.0
ATLANTIC BEACH – BUCCANEER WWTF	FL0023248	1.9	13.4	1.4
JEA – MANDARIN WWTF	FL0023493	7.5	5.34	2.3
JEA – MONTEREY WWTF (operated by UWF)	FL0023604	3.6	11.3	2.6
JEA – HOLLY OAKS WWTF (formerly UWF)	FL0023621	1	8.3	2.1
JEA – SAN JOSE WWTF (formerly UWF)	FL0023663	2.25	10.0	2.9
JEA – JACKSONVILLE HEIGHTS WWTF (formerly UWF)	FL0023671	2.5	10.1	2.9
ORANGE PARK WWTF	FL0023922	2.5	-	3.7
JEA – SAN PABLO WWTF (formerly UWF)	FL0024767	0.75	6.5	3.5

Name of Facility	Facility ID	Permitted Flow (mgd)	1997-98 Nutrients	
			TN (mg/L)	TP (mg/L)
CCUA – MILLER STREET WWTF	FL0025151	4.99	4.5	3.2
JEA – ORTEGA HILLS WWTF (formerly UWF)	FL0025828	0.22	16.8	2.3
JEA – BUCKMAN WWTF	FL0026000	52.5	10.5	4.7
JEA – ARLINGTON WWTF	FL0026441	20	14.3	2.6
JEA – NORTHEAST WWTF (aka JEA – DISTRICT II WWTF)	FL0026450	10	22.7	5.9
JEA – SOUTHWEST WWTF	FL0026468	10	10.5	1.4
JEA – ROYAL LAKES WWTF (formerly UWF)	FL0026751	3.25	7.8	3.8
FWSC – BEACON HILLS SD WWTF	FL0026778	1.3	11.9	2.0
FWSC – WOODMERE SD WWTF	FL0026786	0.7	11.6	1.7
GREEN COVE SPRINGS – SOUTH WWTF	FL0030210	0.5	13.6	2.3
CCUA – FLEMING OAKS WWTF	FL0032875	0.49	3.0	1.9
ATLANTIC BEACH – MAIN WWTF (D001)	FL0038776	3	11.4	2.1
PALATKA WWTF	FL0040061	3	14.7	2.4
ANHEUSER BUSCH – MAIN ST – LAND APP	FL0041530	2.6	3.9	0.3
HASTINGS WWTF	FL0042315	0.12	4.5	0.6
JEA – JULINGTEEN CREEK WWTP	FL0043591	0.476	12.0	3.0
CCUA - FLEMING ISLAND WWTF (combined)	FL0043834	6.365	-	-
UWF – SAINT JOHNS NORTH WWTF	FL0117668	-	6.5	1.7
BRIERWOOD SD – BEAUCLERC STP	FL0023370	-	-	-

Domestic wastewater facilities that discharge to surface waters are concentrated along the St. Johns River from Green Cove Springs to its mouth north of Jacksonville, and farther south near Palatka. The largest domestic wastewater dischargers in the basin are the wastewater treatment facilities associated with the city of Jacksonville in the northern (downstream) end of the basin, including the Buckman Street, Arlington East, JEA District II, Southwest District, and Mandarin wastewater treatment facilities. Several of these facilities participate in reuse programs, and most are seeking ways to either include or improve nutrient removal treatment (FDEP, 1997; Hendrickson and Konwinski, 1998).

All domestic wastewater facilities discharging to the St. Johns River are required, at a minimum, to monitor for conventional pollutants such as total suspended solids (TSS), carbonaceous biological oxygen demand ($CBOD_5$), and fecal coliform bacteria (FDEP, 1997). While most permits do not include nutrient effluent limits, nutrients must be monitored in many systems because of their potential negative effects on surface water, including their role in the formation of nuisance and harmful algal blooms.

Large industrial dischargers in the basin include power plants, pulp and paper mills, chemical plants, and manufacturing plants. The majority of industrial plants send their process wastewater through pretreatment facilities to publicly owned treatment works (POTWs) such as the Buckman plant. Facilities with significant nutrient discharges to the main stem of the LSJR include the Georgia-Pacific Corporation (which produces bleached and unbleached pulp and paper), Stone Container (which changed from a pulp and paper mill to a recycling mill in the 1990s, reducing the volume of discharge), and Anheuser-Busch (a brewery). Remaining discharges include nonprocess wastewater such as cooling water, softener regenerate, and boiler blowdowns, which do not contribute a significant nutrient load.

The original modeling work did not consider the Seminole Electric Power Plant near Palatka as a significant source of nutrients because its discharge is primarily once-through cooling water. However, during the permit renewal process, representatives of Seminole Electric indicated that there was a net increase in nitrogen loads to the St. Johns from their discharge, and a nitrogen load of 5,724 kg/yr from this facility was added to WBID 2213L (there is no net increase in phosphorus loads for the facility).

4.3.2 Estimating Point Source Loads

Point source effluent loads were calculated through a combination of monitoring data and statistical extrapolation to fill monitoring gaps. Point source loads were estimated for only those facilities that discharge directly to the LSJR or to tributary mouths below the head of tide.

Monthly operating report data from treatment facilities were used to create a time-varying input dataset for effluent flow and nutrient, suspended solids, and biological oxygen demand concentrations. Weekly, monthly, or quarterly monitoring data for water quality concentrations were multiplied by daily flow data to determine daily load. For facilities that lack complete chemistry data, mean values from the facility or from similar facilities were used to complete the missing record.

Water quality monitoring data collected for facilities during a 1993 – 95 point source assessment project were also available and were combined into a geographic information system (GIS) database that also includes outfall locations and sewer service coverage area. Outfall locations were then used to identify the appropriate model grids where these sources entered the system.

4.3.3 Municipal Separate Storm Sewer System Permittees

Like other nonpoint sources of pollution, urban stormwater discharges are associated with land use and human activities, and are driven by rainfall and runoff processes leading to the intermittent discharge of pollutants. The 1987 amendments to the Clean Water Act designated certain stormwater discharges from urbanized areas as point sources requiring NPDES stormwater permits. The three major components of the NPDES stormwater regulations are as follows:

- Municipal Separate Storm Sewer System (MS4) permits that are issued to entities that own and operate master stormwater systems, primarily local governments. Permittees are required to implement comprehensive stormwater management programs designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable.

- Stormwater associated with industrial activities is regulated primarily by a multisector general permit that covers various types of industrial manufacturing facilities and requires the implementation of stormwater pollution prevention plans.

- Construction activity generic permits for projects that disturb one or more acres of land require the implementation of stormwater pollution prevention plans to provide for erosion and sediment control during construction and the treatment and management of stormwater to minimize pollution and flooding.

Within the LSJRB, the stormwater systems owned and operated by local governments and the Florida Department of Transportation within the urbanized areas of Duval County are covered by an NPDES MS4 permit. Additionally, several other local governments in the basin have applied for coverage under the Phase 2 NPDES MS4 permit. Within Clay, Duval, Flagler, and St. Johns Counties, 223 industrial facilities have received coverage under the multisector generic permit or the no-exposure exemption.

4.4 Nonpoint Sources

Nonpoint sources of nutrient loading to the LSJR include septic tanks, marinas, silviculture, row crop agriculture, dairies, and stormwater from urban development and tributaries outside of MS4 jurisdictions (including Black Creek, Dunns Creek, Deep Creek, Rice Creek, Julington Creek, Trout Creek, Sixmile Creek, Governors Creek, Clarkes Creek, Cedar Creek, Camp Branch, Mill Branch, and Dog Branch). Unlike traditional point source effluent loads, nonpoint source loads enter at so many locations and exhibit such large temporal variation that a direct monitoring approach is infeasible except for the largest, most significant inputs. Those largest inputs are the upstream boundary of the LSJR at Buffalo Bluff, Dunns Creek, and the downstream boundary at the Atlantic Ocean. For all other nonpoint entry points, watershed modeling was used to complete the external load budget. As part of the revised TMDL, additional nonpoint loading from the Pablo Creek watershed was incorporated into the model.

4.4.1 Pollution Load Screening Model

The watershed model used to estimate nonpoint source loads was the Pollution Load Screening Model (PLSM) (Adamus and Bergman, 1995; Hendrickson and Konwinski, 1998). The PLSM uses a computer-driven GIS framework to develop aggregate whole basin loads of relevant water quality constituents. The computational approach of PLSM calculates constituent loads as the product of concentration and runoff water volume, using nonpoint source pollutant export concentrations specific to one of fifteen different land use classes, and water quantity through a hybrid of the Soil Conservation Service (SCS) curve number method.

In the LSJR application, four significant modifications were made to the model framework, as follows:

The model time step was shortened to seasonal, rather than annual average loading rates, to account for seasonal differences in specific land use export concentrations and runoff quantity;

1. Eight additional water quality variables were added: orthophosphate, total inorganic nitrogen, labile (easily broken down) organic carbon, nitrogen and phosphorus and refractory (slowly broken down) organic carbon, nitrogen, and phosphorus;

2. Land-use loading rates were adjusted to monitoring data collected in the LSJRB using a linear multiple regression best-fit approach based on contributing land use fractions in calibration watersheds; and

3. Hydrologic predictions were improved by using an adjusted water quantity based on the deviations in long-term rainfall patterns.

4.4.2 Atmospheric Deposition

A review by Paerl (1993) has shown that atmospheric deposition contributes 10 percent to 50 percent to the nitrogen budget of estuaries worldwide. In Chesapeake Bay, it has been estimated that 25 percent of the human-caused nitrogen load originates as atmospheric deposition (Fisher and Oppenheimer, 1991). In Tampa Bay, atmospheric deposition has been determined to provide 29 percent of the total nitrogen load (Pribble and Janicki, 1998), making it the second leading source of nitrogen to the bay (Greening *et al.*, 1997).

In their original calculation of nutrient budgets for the LSJR, Hendrickson and Konwinski (1998) estimated that atmospheric wet deposition contributed 15 percent of the total inorganic nitrogen to the river on an annual average basis and 21 percent during the peak algal bloom season, from April through July. However, a reporting unit error was subsequently discovered, and the estimated contribution from atmospheric deposition was reduced to about 4 percent per year. Due to the coarseness of this original estimate, a more detailed atmospheric deposition load assessment was deemed necessary. A recently completed assessment of atmospheric deposition load to the LSJR (Pollman and Roy, 2003) determined that approximately 2 percent of the total nitrogen load, and 10 percent of the inorganic nitrogen load, is supplied through direct atmospheric deposition. The objective of this assessment was to increase the precision of the atmospheric load estimate, and to determine if spatially and temporally varying input is needed to adequately describe nutrient enrichment. The assessment also included a greater number of nutrient forms, dry and wet deposition, an increased number of stations, and an examination of existing data.

Atmospheric deposition of phosphorus was not included in the modeling and TMDL assessment because it is expected to be a very minor source of phosphorus to the basin.

4.4.3 Sediment Flux

The bottom sediment–water interface represents an important boundary for the exchange of nutrients, carbon, and oxygen. As such, the upward and downward flux of these constituents must be assessed to properly account for the water quality characteristics of the water column. This is particularly true of broad, shallow, slow-moving rivers such as the LSJR, where positive (i.e., upward) flux from the sediment undoubtedly makes up a significant portion of the bioavailable nutrient load during certain times of the year. While river sediments represent a transient source of relevant constituents, sediments differ from other sources in that they are not a net positive source (i.e., not a true *external* source), and hence are not listed as a general allocation category in the following section. Over the long term, the accrual of material to the sediment is positive, and long-term net upward sediment flux is negative. In general, long term net accrual to the sediments is proportional to the sources discharging to a particular river reach; thus the effect exerted by transient upward nutrient flux can likewise be considered proportional to the external sources.

Several studies have been performed to quantify the composition and accretion rate of LSJR sediments. Presentations at the October 14-15, 2002, St. Johns River Symposium by Malecki and White; Jaeger and Mausner; Chavan and Ogram; and DePinto, Kaur, and Bierman Jr. summarized findings from these studies. The studies were designed specifically to provide input data necessary for dynamic sediment flux modeling for the LSJR TMDL and PLRG determination.

4.5 Loading Inventory

Estimated nonpoint source loads for the LSJR are shown in Appendix D (Tables D1 – D5), and summarized TN and TP loads for 1995 through 1999 are shown in Figure 5 and Figure 6, respectively. As noted in the pie charts, upstream sources are the dominant TN load to the LSJR, while LSJR nonpoint and point source TP loads are roughly equivalent to the upstream TP load.

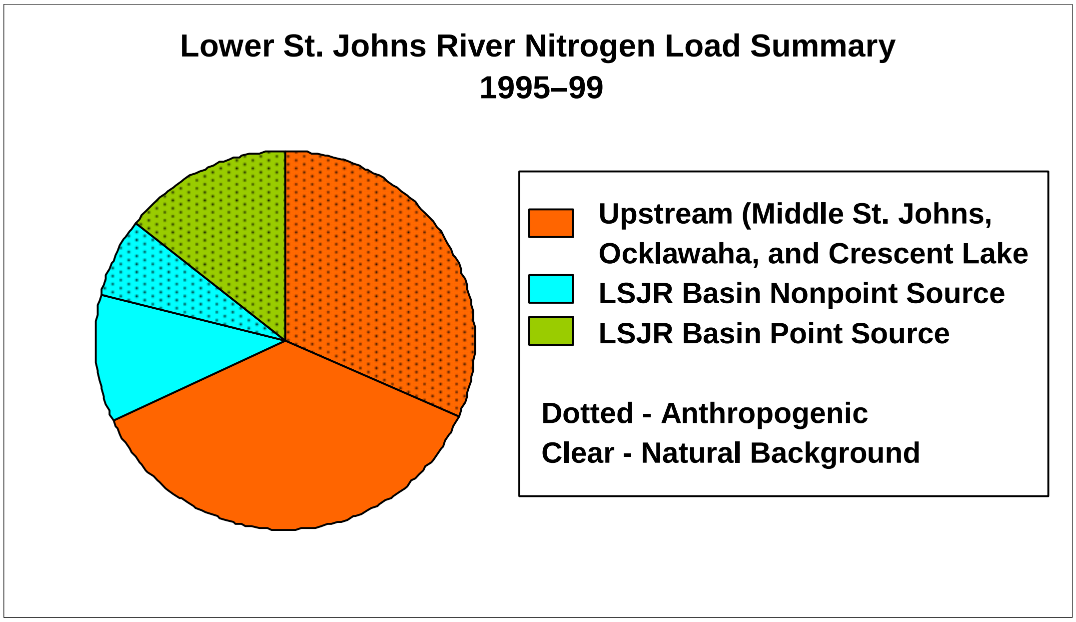

Figure 5 TN Loading to the LSJR by Source Category

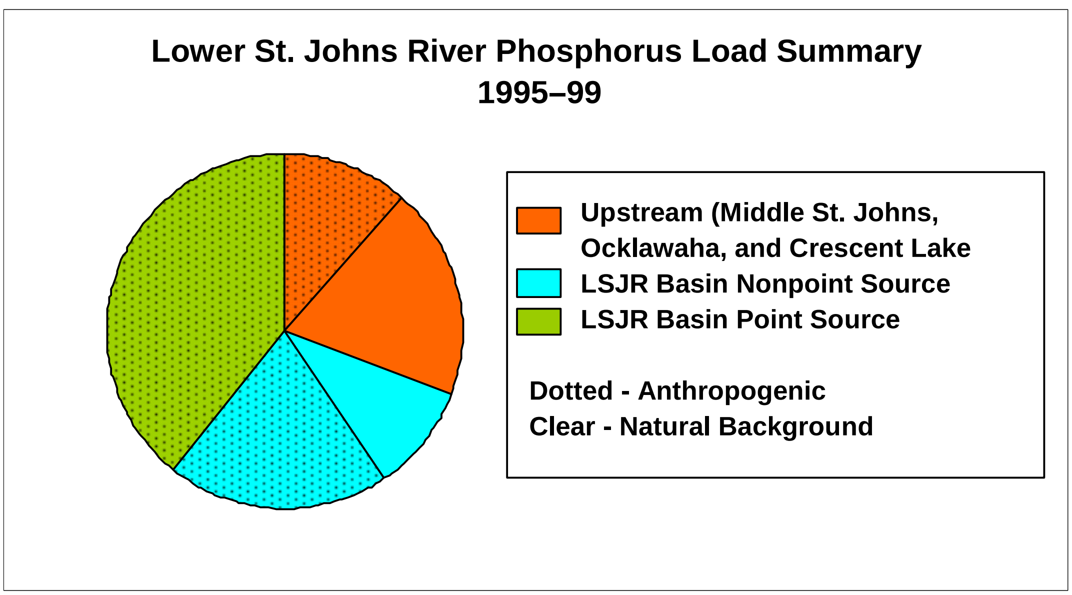

Figure 6 TP Loading to the LSJR by Source Category

5 Determination of Assimilative Capacity

5.1 Use of Modeling

Nutrient enrichment and the resulting problems related to eutrophication tend to be widespread and are frequently manifested at a distance (in both time and space) from their source. Addressing eutrophication involves relating water quality and biological effects (such as photosynthesis, decomposition, and nutrient recycling), as acted upon by hydrodynamic factors (such as flow, wind, tide, and salinity) to the timing and magnitude of constituent loads supplied from various categories of pollution sources. Dynamic computer simulation models have become indispensable tools to describe these relationships. Calibrated models also provide opportunities to predict water quality conditions under alternative constituent loadings.

5.2 Models Used

An interconnected suite of basinwide hydrologic, hydrodynamic, and water quality models have been assembled to develop this TMDL. The suite of models includes the following: 1) a hydrologic model that calculates seasonal runoff and nutrient loads for each sub-basin within the LSJRB (PLSM, described previously); 2) a hydrodynamic model of the river that simulates the mixing and transport of nutrients in the river; and 3) a water quality model that simulates the transformation of nutrients and processes affecting eutrophication in the river.

The river hydrodynamics and salinity of the LSJR were simulated with the Environmental Fluid Dynamics Code (EFDC) model (Hamrick, 1992; Sucsy and Morris, 2002). EFDC solves finite-differenced forms of the hydrostatic Navier-Stokes equations, together with a continuity equation, and transport equations for salinity, temperature, turbulent kinetic energy, and turbulent macroscale. The equations are solved horizontally on a curvilinear, orthogonal grid and vertically on a stretched, sigma-grid. Figure 7 illustrates the grid used for both the hydrodynamic and water quality models. This grid is composed of 2,210 horizontal cells and six vertical layers. The mean cell length is 492 meters, and the maximum achievable time-step for stability of the hydrodynamics simulation is approximately 30 seconds. With the EFDC application to the LSJR, remarkably precise simulations of tidal range, tidal occurrence, and river flow have been achieved (Sucsy and Morris, 2002).

The three-dimensional, time-variable water quality process model code used was the U.S. Army Corps of Engineers Quality Integrated Compartment Model (CE-QUAL-ICM), Version 2 (Cerco and Cole, 1993). CE-QUAL-ICM is among the most sophisticated water quality process models in existence and was originally developed for the Chesapeake Bay Program to examine factors leading to bay hypoxia. Version 1 of the model contained twenty-two variables that simulated oxygen dynamics and included the interaction of three phytoplankton groups, nutrients, and organic carbon. A benthic sediment diagenesis submodel was dynamically coupled with the water column to produce sediment oxygen demand and nutrient fluxes. In its current version, the model has been expanded to include compartments for benthos, zooplankton, and submerged aquatic vegetation. Table 3 summarizes the variables included in the LSJR version of the CE-QUAL-ICM model.

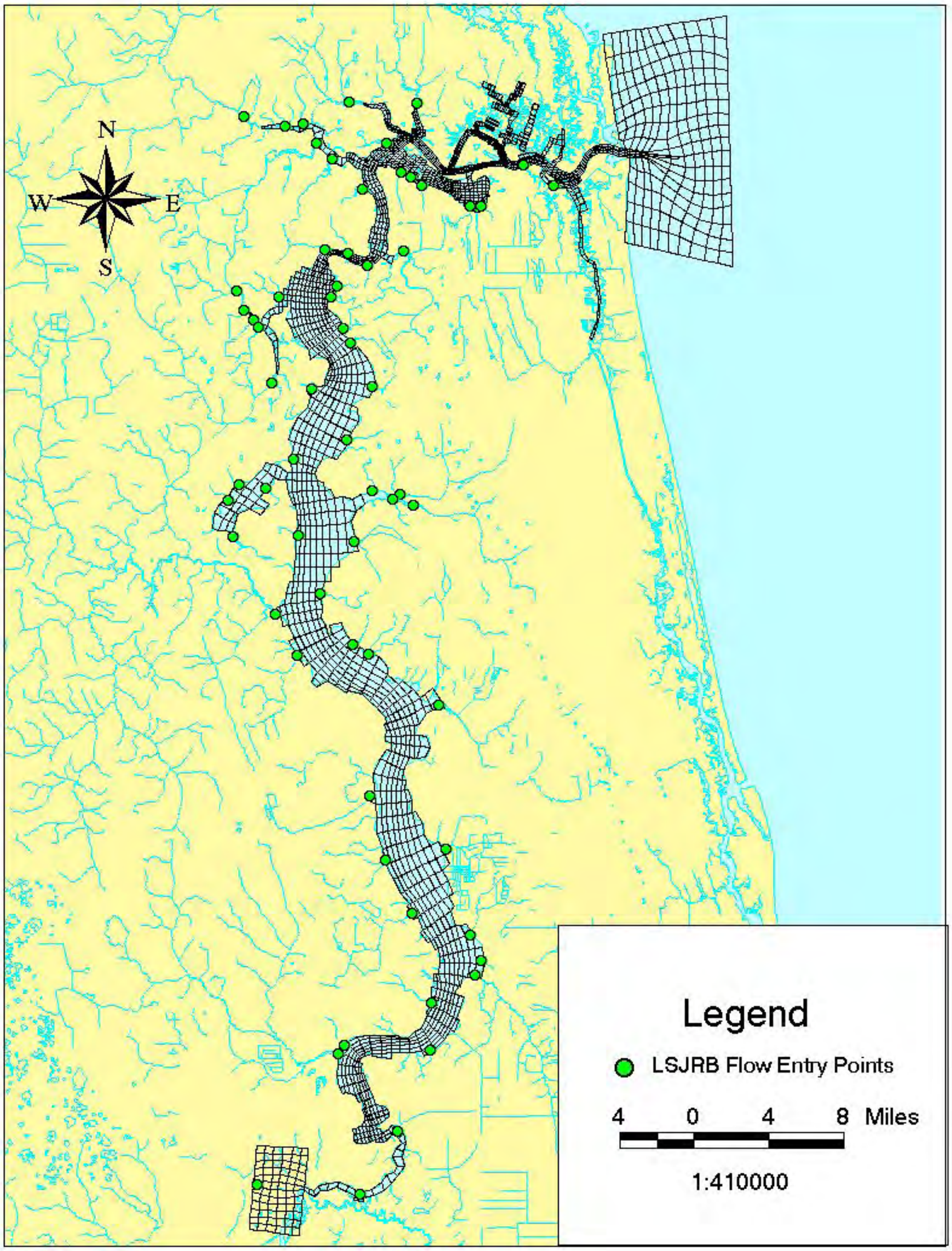

Figure 7 Model Cells for the LSJR Modeling

Table 3 Modeled Variables Included in the CE-QUAL-ICM Model

Model State Variables	
Nitrate + nitrite nitrogen	**Internal phosphorus, algal group 1**
Ammonium nitrogen	**Internal phosphorus, algal group 2**
Urea	**Internal phosphorus, algal group 3**
Refractory dissolved organic nitrogen	**Refractory dissolved organic carbon**
Labile dissolved organic nitrogen	**Labile dissolved organic carbon**
Refractory particulate organic nitrogen	**Refractory particulate organic carbon**
Labile particulate organic nitrogen	**Labile particulate organic carbon**
Total nonvolatile suspended solids	**Green algae biomass as carbon**
Dissolved orthophosphate P	**Cyanobacteria biomass as carbon**
Particulate inorganic P	**Diatoms biomass as carbon**
Refractory dissolved nonorthophosphate P	**Temperature**
Labile dissolved nonorthophosphate P	**Salinity**
Refractory particulate nonorthophosphate P	**Dissolved oxygen**
Labile particulate nonorthophosphate P	**Available silica**
Chemical oxygen demand	**Particulate biogenic silica**
Sediment Model	
State Variables	**Sediment-Water Flux**
Temperature	
Particulate organic carbon	**Sediment oxygen demand**
Sulfide/methane	**Release of chemical oxygen demand**
Particulate organic nitrogen	
Ammonium	**Ammonium flux**
Nitrate	**Nitrate flux**
Particulate organic phosphorus	
Phosphate	**Phosphate flux**
Particulate biogenic silica	
Dissolved silica	**Silica flux**
Benthic algal biomass	**Dissolved oxygen, nutrients**
State Variables for Submersed Aquatic Vegetation	
Deposit feeding benthos as carbon	**Filter feeding benthos as carbon**
Micro zooplankton as carbon	**Meso zooplankton as carbon**
Submerged aquatic vegetation (SAV) shoot biomass as carbon	**SAV root biomass as carbon**
Epiphyte biomass on SAV as carbon	**Inorganic suspended solids**
Benthic algae as carbon	

The U.S. Army Corps of Engineers Research and Development Center (USACE-ERDC) applied CE-QUAL-ICM to the LSJR through a combination of modifications to existing subroutines and through the development of new subroutines and state variables, where appropriate. LSJR-EFDC hydrodynamics were linked to CE-QUAL-ICM.

New subroutines were added to the water quality model, including processes for the photochemical decomposition of colored dissolved organic matter, nitrogen fixation by one of the phytoplankton groups, and a flocculation subroutine to account for the transfer of organic carbon from the dissolved to particulate phase at the turbidity maximum. New state variables added included refractory dissolved organic carbon, nitrogen, and phosphorus. The full sediment diagenesis submodel was utilized and three phytoplankton compartments were simulated (freshwater blue-green algae, freshwater diatoms, and marine diatoms). Both Tillman et al.

(2004) and Sucsy and Hendrickson (2004) document the modifications to CE-QUAL-ICM that were made for this application of the model.

Key changes to the oligohaline/mesohaline component of the water quality model included the following:

1) Separation of the algal communities into a freshwater group and a marine group, with optimum salinities of 5 parts per thousand (ppt) and 20 ppt, respectively;

2) A 50 percent increase in the values for KLDC (the labile dissolved organic carbon dissolution rate) and KLPC (the labile particulate organic carbon dissolution rate), from 0.05/day to 0.075/day;

3) Revision such that all organic carbon from predation was labile; and

4) A new subroutine to allow for nitrogen fixation by one of the phytoplankton groups.

5.3 Model Setup

Hendrickson and Konwinski (1998) described the setup of the PLSM to provide daily flows and loads from contributing sub-basins to the St. Johns River. Figure 7 shows points in the hydrodynamic/water quality grid where sub-basin and point source contributions enter. The upstream boundary for the EFDC and CE-QUAL-ICM models was placed at Buffalo Bluff where total daily river discharge is recorded. Water quality measurements are also routinely collected at Buffalo Bluff and were used to define time variable boundary loads. The downstream boundary for the EFDC and CE-QUAL-ICM models included a tidal water level open ocean boundary and a time series of water quality measurements.

5.4 Model Calibration

Sucsy and Morris (2002) described the calibration procedure and presented hydrodynamic model results for the January 1, 1995 – November 30, 1998 calibration period. Calibration of the EFDC involved examination and adjustments to the following data and input parameters: bottom bathymetry, bottom roughness, tidal water level at the open ocean boundary, the specification of an adequate number of vertical layers, and the specification of a nonreflective upstream open boundary. The model was first calibrated for only the M_2 tide, but then the following components were added: 1) low-frequency, subtidal water level at the ocean boundary; 2) main stemflow at Buffalo Bluff; 3) dynamically-coupled salinity; 4) tributary inflows; and 5) meteorologic components for wind, rainfall, and evaporation. Error analytical techniques used to compare observed and simulated results are described by Sucsy and Morris (2002). These techniques included: 1) regression analysis; 2) calculation of median relative error; 3) comparison of means; 4) calculation of root mean square error (RMSE); and 5)

Kologorov-Smirnov tests for determining the likelihood that two sample populations have identical cumulative distribution functions.

The calibrated EFDC model was provided to USACE-ERDC for linkage to the modified CE-QUAL-ICM model (June 2000 - USACE-ERDC). The USACE-ERDC was contracted to provide a model calibrated to data collected from the December 1, 1995 through November 30, 1998 period. Once delivered to the SJRWMD, the SJRWMD staff performed skill assessments of the model using data collected outside the calibration period (1995, 1996, and 1999). Because of the dramatic differences that occurred in the high-flow and low-flow years of 1998 and 1999, the calibration effort was shifted to these two years to better encompass total potential environmental variation.

The calibration and verification results for the water quality model are presented in Sucsy and Hendrickson (2004), and Tillman et al. (2004). Some of the same analytical techniques used to evaluate the hydrodynamic calibration were used to evaluate the calibration of key water quality parameters at long-term monitoring sites. Example results from a RMSE analysis of DO predictions at Acosta Bridge and Dames Point are shown in Appendix F (Figures F1 and F2, respectively), and calibration results for chlorophyll *a* are shown in Appendix G (Figures G1 – G4).

5.5 Model Results Used To Determine Assimilative Capacity

Based on a recommendation from the Lower St. Johns TMDL Executive Committee, point sources directly discharging to the St. Johns were evaluated based on their 1997–98 discharge flows and loads, with an allowance for anticipated growth over the next few years (rather than assuming permitted design flows and loads). Table 4 summarizes the starting conditions assumed for each facility that were considered as part of the TMDL process. Nonpoint source contributions to the river varied in response to fluctuations in annual rainfall.

The Lower St. Johns TMDL Executive Committee also recommended the addition of two discharges to the TMDL simulations to represent future Apricot (wet weather) and reverse osmosis discharges to the St. Johns into the freshwater portion (WBID 2213I) and marine portion (WBID 2213H). The annual freshwater discharge load was set at 9,961 kg/yr TN and 3,320 kg/yr TP. In the marine portion, an annual discharge load of 4,979 kg/yr TN was used.

Appendix M describes the methodology used to determine projected growth in the basin through 2008 and how changes in urban stormwater were associated with various jurisdictions. These changes were incorporated into the TMDL simulation and are reflected in the allocation spreadsheets found in Appendix J.

The SJRWMD staff presented results from model simulations for the freshwater zone for 1995, 1997, 1998, and 1999. Each year was evaluated with respect to whether the predicted chlorophyll *a* levels exceeded the alternative chlorophyll *a* threshold of 40 µg/L for less than 10 percent of the time. Sucsy and Hendrickson (2004) described the process of assessing the relative influence of anthropogenic nitrogen and phosphorus loads from point and nonpoint sources and the upstream boundary by simulating incremental reductions (25 percent, 50 percent, 75 percent, 100 percent reduction) to the river. Exceedance of the alternative chlorophyll *a* target was calculated for each year, along with the estimated reduction in the anthropogenic load necessary to meet the target. Based on the long-term average results for the four years, the SJRWMD-recommended PLRG was a 30 percent reduction in anthropogenic point, nonpoint, and upstream boundary nitrogen and phosphorus loads.

A similar analysis was completed for the combined oligohaline/mesohaline portion of the river. In these zones, model DO predictions were evaluated to determine whether the "persistent exposure criterion" impairment index (1.0) was met for each set of incremental reductions for each model year (Hendrickson et al., 2003). In this portion of the river, nitrogen was the key nutrient that needed to be reduced to meet the target. Due to depressed DO conditions and a large fish kill in 1999, 1999 was selected as the period to establish nitrogen load reductions to protect the ecological health of the aquatic community. The modeling indicated that a 28.5 percent reduction in anthropogenic point and nonpoint nitrogen loads was needed from within this reach to attain the DO SSAC (percent reductions were calculated based on the initial starting points used by the SJRWMD for 1997-1998). This load reduction was contingent on the 30 percent reduction occurring in the upstream, freshwater reach.

It should be noted that the loading capacities of both portions of the river were originally determined by interpolation and that the interpolated loading capacities were then used to develop detailed wasteload and load allocations. To confirm that the interpolated values (and resultant allocations) would achieve water quality standards, a final model run was made with modeled loads set at the allocated loads. Comparisons between simulation results for the existing 1999 scenario and the final TMDL scenario for both the marine (DO) and freshwater (chlorophyll *a*) portions are presented in Appendix N.

Table 4 Starting Point TN and TP Loads for Point Sources

Name of Facility	Current Flow (mgd)	Projected Increase (mgd)	Permitted Flow (mgd)	Starting Point Flow (mgd)	1997–98 Nutrients TN (mg/L)	1997–98 Nutrients TP (mg/L)	Starting Point TN (lb/day)	Starting Point TP (lb/day)
SMURFIT-STONE CONTAINER CORPORATION	6.88	-	20	8.85	6.8	1.1	502	85
JEFFERSON SMURFIT – JAX	-	-	6	6.0	8.8	1.2	441	58
USN - NS MAYPORT WWTF	0.88	0.044	2	1.03	3.2	2.1	27	18
USN – NAS JACKSONVILLE WWTF	0.955	0.048	3	1.13	8.5	1.7	80	16
GEORGIA-PACIFIC	24.49	-	40	34.2	5.5	1.4	1556	385
JACKSONVILLE BEACH WWTF	2.5	0.13	4.5	3.2	9.1	2.2	242	59

Name of Facility	Current Flow (mgd)	Projected Increase (mgd)	Permitted Flow (mgd)	Starting Point Flow (mgd)	1997–98 Nutrients TN (mg/L)	1997–98 Nutrients TP (mg/L)	Starting Point TN (lb/day)	Starting Point TP (lb/day)
NEPTUNE BEACH WWTF	0.744	-	1.5	0.94	8.8	1.4	69	11
GREEN COVE SPRINGS – Harbor Road WWTF	0.514	0.236	0.75	0.75	9.2	2.9	57	18
WESMINSTER WOODS - (Wesley Manor Retirement Village)	0.03	-	0.09	0.050	4.6	2.0	1.9	0.83
ATLANTIC BEACH – BUCCANEER WWTF	0.91	0.13	1.9	1.13	13.4	1.4	127	13
JEA - MANDARIN WWTF	5.88	1.1	7.5	7.0	5.34	2.3	312	134
JEA – MONTEREY WWTF (operated by UWF)	2.66	0.94	3.6	3.6	11.3	1.6	341	49
JEA - HOLLY OAKS WWTF (formerly UWF)	0	0	1	0	8.3	2.1	0	0
JEA - SAN JOSE WWTF (formerly UWF)	1.65	0.60	2.25	2.25	10.0	2.9	188	55
JEA – JACKSONVILLE HEIGHTS WWTF (formerly UWF)	1.07	0.43	2.5	1.62	10.1	2.9	136	40
ORANGE PARK WWTF	1.16	-	2.5	-	-	3.7	150	41
JEA - SAN PABLO WWTF (formerly UWF)	0.58	0.18	0.75	0.75	6.5	3.5	40	22
CCUA - MILLER STREET WWTF	3.54	1.46	4.99	4.99	4.5	3.2	189	133
JEA - ORTEGA HILLS WWTF (formerly UWF)	0.09	0	0.22	0	16.8	2.3	0	0
JEA - BUCKMAN WWTF	32.04	0.96	52.5	34.02	10.5	4.7	2966	1331
JEA – ARLINGTON WWTF	12.86	5.14	20	18	14.3	2.6	2143	393
JEA - NORTHEAST WWTF (fka JEA - DISTRICT II WWTF)	3.2	1.05	10	5.4	22.7	5.9	1016	263

Name of Facility	Current Flow (mgd)	Projected Increase (mgd)	Permitted Flow (mgd)	Starting Point Flow (mgd)	1997–98 Nutrients		Starting Point	
					TN (mg/L)	TP (mg/L)	TN (lb/day)	TP (lb/day)
JEA - SOUTHWEST WWTF	7.30	4.70	10	10	10.5	1.4	875	116
JEA - ROYAL LAKES WWTF (formerly UWF)	1.64	0.66	3.25	2.99	7.8	3.8	193	94
FWSC - BEACON HILLS SD WWTF	0.66	0.25	1.3	0.99	11.9	2.0	99	16.8
FWSC - WOODMERE SD WWTF	0.43	0.21	0.7	0.64	11.6	1.7	61	8.8
GREEN COVE SPRINGS – SOUTH WWTF	0.21	0	0.5	0.27	13.6	2.3	31	5.3
CCUA – FLEMING OAKS WWTF	0.37	0.03	0.49	0.40	3.0	1.9	10.1	6.5
ATLANTIC BEACH – MAIN WWTF (D001)	1.73	0.07	3	1.8	11.4	2.1	170	31
PALATKA WWTF	2.22	0.35	3	3.0	14.7	2.4	367	60
ANHEUSER BUSCH – MAIN ST - LAND APP	1.46	-	2.6	2.6	3.9	0.3	84	7.6
HASTINGS WWTF	0.085	0.018	0.12	0.103	4.5	0.6	3.9	0.53
JEA - JULINGTEEN CREEK WWTP	0.21	2	0.476	0.476	12.0	3.0	48	12
CCUA – FLEMING ISLAND WWTF (combined)	1.078	-	6.365	-	-	-	172	64
UWF - SAINT JOHNS NORTH WWTF	-	0	-	0	6.5	1.7	0	0
BRIERWOOD SD – BEAUCLERC STP	-	0	-	0	-	-	0	0
SEMINOLE ELECTRIC COOPERATIVE, INC PALATKA PLANT,			7.46			-	346	-

6 Determination of the TMDL

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (Waste Load Allocations, or WLAs), nonpoint source loads (Load Allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}$$

As mentioned in Section 4.1, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\textbf{TMDL} \cong \sum \textbf{WLAs}_{\textbf{wastewater}} + \sum \textbf{WLAs}_{\textbf{NPDES Stormwater}} + \sum \textbf{LAs} + \textbf{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because 1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and 2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as a mass per day).

WLAs for stormwater discharges are typically expressed as "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations which provide that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. See 40 CFR § 130.2(i). TMDLs for the LSJR are expressed in terms of kilograms per year, and represent the maximum annual TN and TP load the freshwater and estuarine reaches of the river can assimilate and maintain the narrative nutrient criterion (Table 5 and Table 6). As described in the note for Tables 5 and 6, a daily expression of the TMDLs can be calculated by dividing the annual average load by 365.25. The resultant loads represent the total maximum annual average daily loads. However, the TMDLs to be implemented are those expressed on a mass per year basis, and the expression of the TMDL on a mass per day basis is for information purposes only. As noted in Table 6, the TMDL for the estuarine portion of the river is for TN only because nitrogen is the limiting nutrient for this portion of the river.

The allocation to specific wastewater facilities is provided in Appendix J. The division of the available assimilative capacity between the WLA and LA were determined using information about individual sources and source categories. The allocation methodology followed the recommendations in the *2001 Report to the Governor and Legislature on the Allocation of Total Maximum Daily Loads* (FDEP, 2001), with site-specific revisions to the allocation methodology recommended by the LSJR TMDL Executive Committee. Under this approach, initial reductions for the river were targeted at nonpoint source loads assuming the implementation of BMPs. As BMP implementation alone did not result in sufficient reductions, all anthropogenic sources, including the upstream load, were reduced by the same percentage until the assimilative capacity was met, with the exception that prior treatment or prior commitments in treatment improvements was taken into account for individual point sources.

For the case of domestic wastewater facilities in the marine portion of the river, the allocations are based on their starting point flow and a target TN concentration of 5.4 mg/L. Using this approach, facilities that already provided advanced waste treatment (typically defined as a TN of 3 mg/L) did not have to make additional reductions, and in fact, could increase their discharged load or generate credits.

Allocation calculations were conducted using an Excel spreadsheet, and table versions of the spreadsheets used to allocate loadings in the freshwater and estuarine portions of the river, are provided in Appendix J (interested parties can request an electronic copy of the spreadsheet if they would like to see spreadsheet formulas).

Table 5 TMDL Components for the Freshwater Portion of the LSJR

WBIDs	Parameter	TMDL (kg/year)	WLA[2] (kg/year)	LA (kg/year)	MOS
2213I to 2213M	Total Nitrogen	8,571,563	236,695	8,394,868	Implicit
2213I to 2213M	Total Phosphorus	500,325	46,357	453,968	Implicit

Table 6 TMDL Components for the Estuarine Portion of the LSJR

WBIDs	Parameter	TMDL (kg/year)	WLA (kg/year)	LA (kg/year)	MOS
2213A to 2213H	Total Nitrogen	1,376,855	1,027,590	349,265	Implicit

[2] As described in Section 6.2, this WLA includes a percent reduction in current loading from sources covered by the NPDES Stormwater Program.

Note: To calculate the total maximum annual average daily load that should be expected divide the annual average load by 365.25.

It should be noted that some facilities requested FDEP combine their WLAs into an aggregate WLA to allow flexibility so that reductions from one facility can be shifted to another as long as the net reduction reaches the aggregate WLA. For these aggregate allocations, FDEP plans to issue watershed permits that will require compliance with the aggregate WLA.

6.2 Load Allocation

The LA for the freshwater portion of the LSJR includes the following loads: 1) the natural background nonpoint source load (which includes background upstream loads from the Middle St. Johns River [MSJR] and background loads from Dunns Creek); 2) augmented nonpoint source loads (again including augmented upstream loads from the MSJR and Dunns Creek); and 3) atmospheric deposition. To determine the allocation between the WLA and LA, the augmented TN and TP nonpoint source loads were first reduced by the amounts estimated for the implementation of applicable BMPs on agricultural lands and urbanized areas, and then augmented nonpoint sources (excluding atmospheric deposition) and point sources were reduced by the same percentage until the assimilative capacity was met. Using this approach, the LA takes into account reductions expected in the upstream load from the MSJR. It should also be noted that the LA includes loading from stormwater discharges regulated by FDEP and the water management districts that are not part of the NPDES Stormwater Program (see Appendix E).

Allocations of urban nonpoint source loads to individual jurisdictions in the freshwater portion of the river are provided in Appendix J. These allocations were developed in the same manner as was conducted for MS4s (see Appendix M) and were expressed as percent reductions rather than load.

The load allocation for the marine portion of the river was developed in the same manner as was conducted for the freshwater portion. Allocations to individual jurisdictions (shown in Appendix J) were expressed as percent reductions.

6.3 Wasteload Allocations

The WLA for the estuarine portion of the river is a combination of the sum of the WLAs for all of the NPDES wastewater facilities and the stormwater discharges from the MS4 jurisdictions (Appendix J). While the loads for individual MS4s were calculated, the allocations to the MS4s are expressed as percent reduction rather than loads. The methodology to determine the required percent reduction in urban stormwater for each MS4 discharging to the estuarine portions of the river is described in Appendix M.

The WLA for the freshwater portion of the river is the sum of the WLAs for all of the NPDES wastewater facilities and a percent reduction assigned to stormwater discharges subject to FDEP's NPDES Stormwater Program. As was done in the marine portion of the river, allocations to each MS4 in the freshwater portion of the river were expressed as a percent reduction.

It should be noted that any MS4 permittee will only be responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

6.4 Aggregate Loads and Pollutant Trading

Some facilities requested FDEP combine their WLAs into an aggregate WLA to allow flexibility in how they meet the required reductions in load. While this aggregation was straightforward for entities with multiple wastewater facilities, the aggregation was slightly more complex for municipalities that wanted to aggregate their wastewater and MS4 allocations because the allocations to MS4s were expressed as percent reductions. The approach was to simply convert the percent reduction back into a load using the loading in the allocation spreadsheet.

This approach clearly works for the TMDL for the freshwater portion of the river, which is based on a long-term average condition (based on the chlorophyll *a* target of not to exceed 40 ug/L for more than 10% of the time). This approach also works in the marine portion of the river, even though the TMDL is based on a dry year [1999 was the worst-case year for dissolved oxygen, when tributary flows were low, nutrients were concentrated in the river due to less dilution, and residence times were longer]. Model runs[3] indicate that the percent reductions needed in other model years are about half of the reductions in 1999 (15% reduction required in 1996 and 1997, compared to the 28.5 % reduction required in 1999), while the urban stormwater loads for these years are less than twice the 1999 load. As such, it is adequately protective to use the 1999 load for aggregation purposes.

For the aggregate allocations, FDEP plans to issue watershed permits that will require compliance with the aggregate WLA. These permits will be in addition to the facilities current permits, and will focus on compliance with the WLA.

This approach of converting the percent reduction back into the allowable load for 1999 is also applicable if MS4s decide to meet their required reductions through water quality credit trading. The WLAs given to point sources can be modified via trading as long as the overall load does not exceed the TMDL. The combined WLA (both total and facility-specific) is provided to allow flexibility so that reductions from one discharger can be shifted to another as long as the net allocation achieves the TMDL. FDEP plans to address the permitting process and requirements for water quality credit trading, including trading factors, in the Basin Management Action Plan (BMAP) for the TMDL.

[3] These model runs were evaluated because the Department was concerned that the amount of load aggregated, if based on the dry year loading, could conceivably be inadequately protective during wetter years when MS4 loads would be higher, depending on the percent reduction required for the wetter years.

6.5 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (FDEP, 2001), an implicit margin of safety (MOS) was assumed in the development of this TMDL. An implicit MOS was provided by the conservative decisions associated with a number of modeling assumptions, the development of site-specific alternative water quality targets, and the development of the assimilative capacity.

In the freshwater zone, multiple years of phytoplankton and zooplankton field measurements were evaluated to establish the site-specific chlorophyll *a* level beyond which zooplankton abundance and diversity started to decline. Hydrodynamic/water quality simulations over four different years were then evaluated to determine the appropriate long-term average TN and TP load reductions necessary to meet the chlorophyll *a* target. These four years represent flows that were slightly drier than average conditions and, given that the effects of nutrient impairment are more prominent in dry conditions, this long-term, yet dry period is considered conservative.

The expression of the TMDLs also provided an implicit MOS because equal percent reductions of both TN and TP were required, even though both nutrients may not be the limiting factor for a given year in the freshwater zone. In addition, reductions were based on meeting the target within all five WBIDs in the freshwater zone. As such, the “worst case” WBID controlled the amount of reduction needed. Finally, point source flows and loads used in the WLA for the freshwater zone were based on existing flows and loads with an allowance for growth rather than assuming permitted limits. An implicit MOS is provided by this approach because it would be extremely unlikely that all of the point sources would simultaneously discharge at their full WLA.

Conservative assumptions were also part of the development of the TMDL for the oligohaline/mesohaline portion of the river. As in the freshwater zone, four different years were simulated. However, in this case, the worst-case year (1999) was used to establish necessary nitrogen load reductions in the oligohaline/mesohaline zone because the controlling factor, DO, can result in impairment in shorter time frames than increased algal biomass. In 1999, there were reduced rainfall and increased residence times, which resulted in reduced DO levels and a large fish kill. As in the freshwater zone, the percent reduction needed for the oligohaline/mesohaline zone was based on ensuring that the target was met in all of the WBIDs in these zones.

Another conservative assumption involved the methodology used to establish the DO SSAC in the marine portion of the river. For example, a minimum DO of 4.0 mg/l was specified and certain conservative assumptions were made regarding larval recruitment and growth in the development of the SSAC.

Finally, point source flows and loads used in the WLA for the oligohaline/mesohaline zones were based on existing flows and loads with an allowance for growth rather than assuming permitted limits. As noted previously, an implicit MOS is provided by this approach because it is extremely unlikely that all of the point sources would simultaneously discharge at their full WLA.

6.6 Seasonal Variability

Seasonal variability was assessed during the development of this TMDL as part of the development of the site-specific water quality targets and the determination of the assimilative capacity. The site-specific targets developed for the freshwater and oligohaline/mesohaline zones account for the seasonal cycles in algal growth. In the freshwater zone, the critical period occurred during April – August, when excessive algal growth has led to imbalances in the algal community structure (dominance by only a few species) and impacts to the food web (undesirable prey for zooplankton and fish species). The chlorophyll *a* target for the freshwater zone (40 µg/L not to be exceeded more than 10 percent of the time) was specifically designed to prevent algal blooms of sufficient duration to cause these imbalances in flora and fauna in the future.

The TMDL for the oligohaline/mesohaline zone also accounted for seasonal variability. As discussed earlier in the MOS section, the summer of 1999 was a critical period, during which DO was below 4.0 mg/L at levels and for durations that could adversely impact the aquatic fauna in the oligohaline/mesohaline zones. The method used to develop the DO target accounted for these critical, seasonal (and diurnal) periods and ensures that excursions of DO levels below the chronic threshold will not occur at a magnitude or duration that would result in impacts to aquatic fauna.

7 Next Steps and Beyond

TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated by FDEP during its BMAP development process and subsequent watershed management cycles. EPA and FDEP recognize that it may be appropriate to revise the TMDL in the future when more information has been collected and analyzed. With such possible revisions in mind, this TMDL is characterized as an adaptive management TMDL. The best information available at the time is used to develop an adaptive management TMDL, However, the adaptive management approach recognizes that additional data and information may be necessary to validate assumptions of the TMDL, and that the additional information should be pursued to improve the next iteration of the TMDL

One of the key issues that determined the allowable loading for this TMDL was FDEP's interpretation of the narrative nutrient criterion for the water quality target (40 ug/L not to be exceeded more than 10% of the time) for the TMDL. Given the importance of the water quality target, FDEP plans to work with stakeholders to conduct monitoring of the river (see Section 3.3) designed to further evaluate the water quality target for nutrients and to determine the effectiveness of the pollution control activities required by this TMDL.

It should also be noted that this TMDL does not directly address nutrient impacts on submerged aquatic vegetation (SAV). FDEP and the SJRWMD agree that the TMDL would have ideally addressed nutrient impacts on the SAV community in the LSJR. In fact, one of the reasons the CE-QUAL-ICM model was selected for this TMDL was that it had the capability to simulate SAV, including epiphytic growth effects on SAV. However, specific studies of the effects of nutrients, light, and salinity on the dominant SAV species in the LSJR were not completed in time to allow for the SAV modeling component of CE-QUAL-ICM to be used for this version of the TMDL. The SJRWMD is actively pursuing these studies and they should be completed over the next two years (see Appendix K for a list of studies that will provide the necessary information to model SAV response). As this information becomes available, the model code will be revised to incorporate a site-specific light model and additional state variables that influence SAV growth, and the model will be re-calibrated for use in the next iteration of the TMDL. If there are any changes in the estimate of the assimilative capacity as result of the revisions to the water quality target or model code to address SAV, the rule adopting this TMDL will be revised, providing a point of entry for interested parties.

8 REFERENCES

Adamus, C.L., and M.L. Bergman. 1995. *Estimating nonpoint source pollution loads with a GIS screening model*. Water Resources Bulletin 31(4):647-655.

Bricker, S.B, C.G. Clement, D.E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. 1999. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries.* September 1999. National Ocean Service, National Oceanic and Atmospheric Administration. 71pp.

Burkholder, J.M., and H.B. Glasgow, Jr. 1997a. Pfiesteria piscicida *and other* Pfiesteria-*like dinoflagellates: Behavior, impacts, and environmental controls.* Limnology & Oceanography 42(5, part 2):1052-1075.

Burkholder, J.M., and H.B. Glasgow, Jr. 1997b. *Trophic controls on stage transformations of a toxic ambush-predator dinoflagellate.* J. Euk. Microbiology 44:200-205.

Cerco, C., and T. Cole. 1993. *Three-dimensional eutrophication model of Chesapeake Bay*. Journal of Environmental Engineering. 119:1006-1025.

EPA. 1999. *Ambient water quality criteria for dissolved oxygen (salt water): Cape Cod to Cape Hatteras.* Office of Water Office of Science and Technology. September 1999. EPA 822-D-99-002. 55pp.

EPA. 2001. Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters. October 2001. Office of Water. EPA 822-B-01-003.

FDEP. 2001. *A Report to the Governor and the Legislature on the Allocation of Total Maximum Daily Loads in Florida*. February 2001. Bureau of Watershed Management.

FDEP. 2002. *Basin Status Report for the Lower St. Johns River Basin.* Bureau of Watershed Management.

Fisher, D.C. and M. Oppenheimer. 1991. *Atmospheric nitrogen deposition and the Chesapeake Bay estuary*. Ambio 20(3-4): 102-108.

Floyd, S.S., E.M. Irwin, and D.A. Evans, editors. 1997. Florida statistical abstract. University of Florida, Bureau of Economic and Business Research. Gainesville: University Presses of Florida.

FMRI. 2002. *Fisheries Independent Monitoring Program 2001. Annual Data Summary Report.* Florida Marine Research Institute, St. Petersburg, Florida.

Greening, H., L.K. Dixon, A. Squires, P. Hessling, T. D'Aquila and T. Rogers. 1997. *Contribution of atmospheric deposition to nitrogen and toxic materials loadings to Tampa Bay*. In: Proceedings, Tampa Bay Area Wide Scientific Information Symposium 3: Applying Our Knowledge. S. Treat, Ed. 396 pp.

Hamrick, J.M. 1992. *A three-dimensional environmental fluid dynamics computer code: Theoretical and computational aspects.* Special Report 317. College of William and Mary, Virginia Institute of Marine Sciences, Virginia.

Hendrickson, J., and J. Konwiniski. 1998. *Seasonal nutrient import-export budgets for the Lower St. Johns River, Florida.* St. Johns River Water Management District.

Hendrickson, J., and W. Magley. 2001. *Development of total maximum daily loads and pollutant load reduction goals for the Lower St. Johns River Basin: Plan of Study.* St. Johns River Water Management District.

Hendrickson, J., N. Trahan, E. Stecker, and Y. Ouyang. 2004. *Estimation and Assessment of the Current and Historic External Load of Nitrogen, Phosphorus and Organic Carbon to the Lower St. Johns River for the Fulfillment of TMDL and PLRG Objectives.* Department of Water Resources, St. Johns River Water Management District, Palatka, Florida.

Hendrickson, J.C., E.F. Lowe, D. Dobberfuhl, P. Sucsy, and D. Campbell. 2003. *Characteristics of Accelerated Eutrophication in the Lower St. Johns River Estuary and Recommended Targets to Achieve Water Quality Goals for the Fulfillment TMDL and PLRG Objectives.* Department of Water Resources, St. Johns River Water Management District, Palatka, Florida.

Janicki, A. and G. Morrison. 2000. Developing a Trophic State Index for Florida's Estuaries. Submitted to the Florida Department of Environmental Protection. Janicke Environmental, Inc., St. Petersburg, Florida.

Paerl, H.W. 1993. Emerging role of atmospheric nitrogen deposition in coastal eutrophication: biogeochemical and trophic perspectives. Can. J. Fish. Aquat. Sci. 50: 2254-2269.

Phlips, E.J., M. Cichra, F.J. Aldridge, J. Jembeck, J. Hendrickson, and R. Brody. 2000. *Light availability and variations in phytoplankton standing crops in a nutrient-rich blackwater river*. June 2000. Limnology & Oceanography 45:(4) 916-929.

Pollman, C.D. and S. Roy, 2003. *Examination of Atmospheric Deposition Chemistry and Its Potential Effects on the Lower St. Johns Estuary*. Final Report Submitted to St. Johns River Water Management District, Contract No. SE706AA. Tetra Tech, Inc., Gainesville, Florida.

Pribble, R.J., and A.J. Janicki. 1998. *Atmospheric deposition contributions to nitrogen and phosphorus loadings in Tampa Bay: Intensive wet and dry deposition collection and analysis.* Report prepared for: Tampa Bay National Estuary Program, St. Petersburg, FL.

SJRWMD. 1993. *SWIM Plan for the Lower St. Johns River.* January 1993, Palatka, Florida.

Sucsy, P.V., and F.W. Morris. 2002. *Calibration of a three-dimensional circulation and mixing model of the Lower St. Johns River*. Technical Memorandum No., Draft 1.1. St. Johns River Water Management District.

Sucsy, P., and J. Hendrickson. 2004. *Calculation of nutrient reduction goals for the Lower St. Johns River by application of CE-QUAL-ICM, a mechanistic water quality model.*

Department of Water Resources, St. Johns River Water Management District, Palatka, Florida.

Tillman, D., Cerco, C., Noel, M., Martin, J., and Hamrick, J. 2004. *Three-dimensional eutrophication model of the lower St. Johns River, Florida.* ERDC TR-04-xx, US Army Engineer Research and Development Center, Vicksburg, Mississippi.

.